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Original article

A retrospective comparative ten-year study of cumulative survival rates of remaining teeth in large edentulism treated with implant-supported fixed partial dentures or removable partial dentures

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Abstract

Purpose: This study aimed to compare the survival rates of remaining teeth between implant-supported fixed dentures (IFDs) and removable partial dentures (RPDs) in patients with large edentulous cases. The second goal was to assess the risk factors for remaining tooth loss.
Materials and methods: The study subjects were selected among those who received prosthodontic treatment at Okayama University Dental Hospital for their edentulous space exceeding at least four continuous missing teeth. Twenty-one patients were included in the IFD group and 82 patients were included in the RPD group. Survival rates of remaining teeth were calculated in three subcategories: (1) whole remaining teeth, (2) adjacent teeth to intended edentulous space, and (3) opposing teeth to intended edentulous space.
Results: The ten-year cumulative survival rate of the whole remaining teeth was significantly higher in the IFD group (40.0%) than in the RPD group (24.4%). On the other hand, there was no significant difference between two groups in the survival rate of teeth adjacent or opposing to intended edentulous space. A Cox proportional hazard analysis revealed that RPD restoration and gender (male) were the significant risk factors for remaining tooth loss (whole remaining teeth).
Conclusions: These results suggest that IFD treatment can reduce the incidence of remaining tooth loss in large edentulous cases.

Keywords: Survival rate; Implant-supported fixed denture; Removal partial denture; Remaining teeth; Risk factor

1. Introduction

It is widely recognized that fixed and removable partial dentures are the most important nonsurgical prosthetic treatment options to restore patients' edentulous space. Nevertheless, these treatment modalities are also known to occasionally contribute to shorten the longevity of the abutment teeth due to mechanical overload, which is critical in large edentulous areas. For instance, fixed partial dentures (FPDs) support excessive occlusal forces that are transmitted to abutment teeth in a non-axial direction. Additionally, grinding of healthy dentine of the abutment teeth is assumed to increase the risk of caries. Regarding the removable partial dentures (RPDs), it has been reported that RPDs decrease the survival rates of teeth adjacent to the edentulous space in bounded edentulous cases and free-end edentulism [1,2]. The periodontal condition of abutment teeth is often aggravated by torqueing forces from the RPDs [3–5].

On the other hand, implant-supported fixed denture (IFD), which stands alone, has been speculated to protect teeth adjacent to the edentulous space without injuring them. However, only a few studies have evaluated the prognosis of remaining teeth in subjects treated with IFDs. This study is part of a series of reports, in which we compared IFDs, FPDs and RPDs regarding their protective effect on the remaining dentition. The previous paper focused on the survival rates of remaining teeth in bounded edentulous spaces [6]. This report

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aimed to compare the survival rates of remaining teeth between IFDs and RPDs in patients with large edentulous cases. In addition, risk factors for remaining teeth loss were also tabulated and assessed. The null hypothesis was that no significant difference in survival rates would be observed between the two treatment options.

2. Materials and methods

2.1. Study population

The intended subjects were 453 patients (IFDs: 126 patients, RPDs: 327 patients) selected among those who presented at least one remaining tooth and received IFD or RPD treatment for their edentulous space exceeding at least four continuous missing teeth in the same jaw, at the Fixed Prosthodontic Clinic of Okayama University Hospital, Okayama, Japan between April 1997 and March 2007. Exclusion criteria were those patients (1) who were installed other IFDs or RPDs except for the intended edentulous space, (2) who were scheduled an extraction of remaining tooth/teeth before IFD or RPD installation, and (3) whose data concerning the analyzed predictor variables were lacking. In response, 350 patients were excluded, and a total of 103 patients were considered as the actual sample (IFD group: 21 patients, RPD group: 82 patients). This study protocol was reviewed and approved by the Ethical Committee for Human Study of Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences (No. 213).

2.2. Primary endpoint and candidates of risk factors for remaining teeth loss

The observation period in both IFD and RPD groups started at the date of final restoration insertion and finished on March 31st, 2010. Patients' follow-up visits were scheduled at least every six months, and the treating dentist checked the status of all restorations and the periodontal condition. In addition, relining of the RPD was performed when the attending doctor judged necessary.

The primary endpoint of this study was defined as extraction or an intention/decision to extract any remaining tooth, as so described in the hospital chart. Causes for tooth extraction were classified as: caries, root fracture, periodontal, and periapical lesions. The description of each cause of tooth extraction was diagnosed based on patient's subjective complaints as well as clinical and radiographic examinations. Data were assessed twice by one investigator (S.Y.). Patients who did not return to the hospital within two years prior to the end of the study were regarded as censored cases, for whom the complication-free period was established to be from the date of final treatment completion to the last follow-up visit.

The analyzed predictor variables for the aforementioned endpoint were as follows: (1) restoration (IFD or RPD), (2) age at prosthesis insertion, (3) gender (male or female), (4) edentulous arch (maxilla or mandible), (5) edentulous pattern (bounded or free-end), (6) total number of remaining teeth, (7) number of missing teeth at the intended edentulous space, and (8) Eichner index [7]. Since the difference of occlusal supporting area could influence the prognosis of remaining teeth, Eichner index was involved in the list of predictor variables.

2.3. Identification of survival rates of remaining teeth

Survival analysis was performed to evaluate the prognosis of remaining teeth in both IFD and RPD groups. First, the cumulative survival rates were calculated by using the actuarial method to understand the tendency of all remaining teeth loss and over time transition of the actual number. Survival curves were then calculated for the remaining teeth in three different subcategories: (1) whole remaining teeth, (2) adjacent teeth to intended edentulous space, and (3) opposing teeth to intended edentulous space. If there happened an incidence of tooth loss in one subcategory, observation of all categories was also finished. Furthermore, the causes for tooth loss were classified into the following four categories: (1) root fracture, (2) caries, (3) periodontal, and (4) periapical lesions. Diagnoses of these conditions were based on patient's subjective complaints as well as clinical and radiographic examinations.

2.4. Statistical analysis

Chi-square test and *t*-test were used to compare baseline data between IFD and RPD groups regarding age at prosthesis insertion, gender, functional duration of prosthesis, missing unit, missing pattern, remaining teeth number, missing teeth number at intended edentulous space, and Eichner index. Survival curves were calculated by Kaplan–Meier analysis [8]. The log-rank test was used to compare the survival curves between two groups [9]. Finally, the Cox proportional hazards regression model [10] was performed with all analyzed predictor variables simultaneously, in order to identify the significant risk factors for remaining tooth loss in both IFD and RPD groups. This analysis was also performed for each of the three aforementioned subcategories of remaining teeth (whole remaining teeth, adjacent and opposing teeth to edentulous space). Data analysis was performed with StatView ver5.0 for Windows statistical software package (SAS Institute Inc., Cary, NC, USA), and the level of statistical significance was set at $p < 0.05$.

3. Results

3.1. Baseline data

As shown in Table 1, baseline data comparison revealed a significant difference between IFD and RPD groups in regard to the mean age at prosthesis insertion (IFD group: 46.4+/−15.0 years, RPD group: 60.6+/−12.7 years; $p < 0.001$), and gender (male/female: 15/6 for IFD group, 35/47 for RPD group; $p = 0.02$).

Table 1
Demographic data of IFD and RPD groups.

	IFD group $N = 21$	RPD group $N = 82$	p-Value
Mean age (y)	46.4 ± 15.0	60.6 ± 12.7	**<0.01**
Male/female	6/15	35/47	**0.02**[a]
Functional duration (y)	4.9 ± 4.2	5.1 ± 3.4	0.28[b]
Missing unit (maxilla/mandible)	12/9	62/20	0.09[a]
Missing pattern (free-end/bounded)	12/9/	61/21	0.12[a]
No. of remaining teeth	20.1 ± 5.3	18.8 ± 4.0	0.24[b]
No. of missing teeth	6.1 ± 3.0	6.2 ± 3.2	0.9[b]
Eichner index (A/B1/B2/B3)	8/3/8/2	16/3/52/11	0.05[a]

Values with ± are mean ± SD.
Bold: statistically significant.
[a] χ^2-test.
[b] t-test.

Table 2
Cumulative survival rates of remaining teeth calculated by actuarial method in each group.

	Functional duration (y) Start≥ end<	No. of remaining teeth at the start point of each period	No. of tooth loss in each period	No. of cumulative tooth loss	No. of censored cases	No. of cumulative censored cases	Cumulative survival rate (%)
IFD group	0–1	21	0	0	5	5	100
		16	1	1	2	7	100
		13	0	0	1	8	93.3
		12	0	0	0	0	93.3
		10	0	0	0	0	93.3
		8	1	2	0	0	93.3
		5	0	0	0	0	80
		4	0	0	0	0	80
		4	1	3	0	0	80
		3	1	4	0	0	60
		2	0	0	0	0	40
		1	0	0	0	0	40
RPD group		82	9	9	10	10	100
		61	9	18	2	12	88.2
		50	7	25	3	15	74.9
		39	5	30	0	0	64
		27	5	35	0	0	55
		18	2	37	0	0	44
		12	1	38	0	0	38.5
		11	1	39	0	0	35.3
		7	1	40	0	0	31.6
		4	0	0	0	0	26.3
		4	0	0	0	0	26.3
		1	0	0	0	0	26.3

3.2. Survival analysis by actuarial method

Table 2 shows the ten-year cumulative survival rates of both IFD and RPD groups calculated by the actuarial method. The survival rates of remaining teeth in both IFD and RPD groups were 40.0 and 26.3%, respectively. Additionally, loss of remaining teeth in RPD group tended to occur relatively earlier (62.5% cases were occurred within three years after insertion of prosthesis) than in IFD group.

3.3. Cumulative survival rates of remaining teeth

This retrospective cohort study revealed that the ten-year cumulative survival rate of the whole remaining teeth was significantly higher in the IFD group than in RPD group (IFD: 40.0%, RPD: 24.4%; $p < 0.05$) (Fig. 1a). On the other hand, there was no significant difference between the two groups when analysis was performed for either the adjacent teeth (IFD: 62.2%, RPD: 61.8%; $p > 0.05$) (Fig. 1b), or the opposing teeth to edentulous space (IFD: 75.0%, RPD: 83.8%; $p > 0.05$) (Fig. 1c).

3.4. Prevalence and cause of tooth loss

With regard to the whole remaining teeth, 19% of patients in IFD group (4/21 patients) and 48.8% of patients in RPD group (40/82 patients) lost at least one tooth during the observation period (Fig. 2). The causes of tooth loss in IFD group were

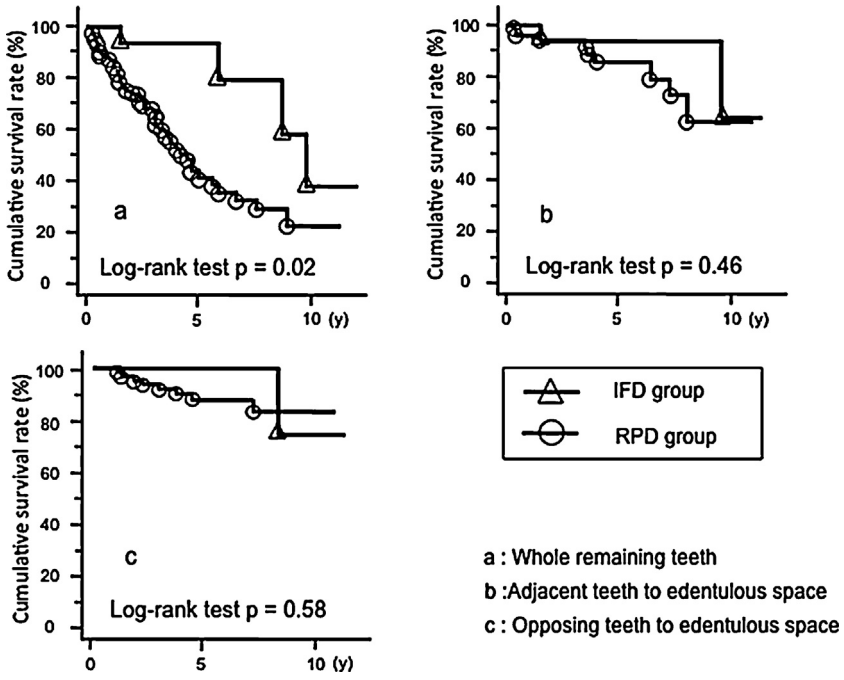

Fig. 1. Survival curves of remaining teeth compared between implant-supported fixed dentures and removable partial dentures by Kaplan–Meier analysis. The *p*-value was obtained by the log-rank test. (a) survival curves for whole remaining teeth, (b) survival curves for teeth adjacent to intended edentulous space, and (c) survival curves of teeth opposed to intended edentulous space. *Y*-axis: Cumulative survival rate (%), *X*-axis: observation period (year).

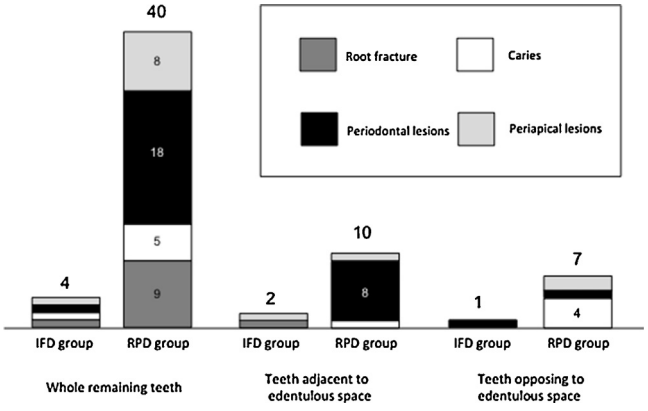

Fig. 2. Prevalence and cause of remaining tooth loss in both IFD and RPD groups. Data are shown for the three analyzed subcategories (whole remaining teeth, teeth adjacent to intended edentulous space and teeth opposed to intended edentulous space). Total number of tooth loss during observation period in each group is indicated at the top of each bar.

diverse; however, in the RPD group, approximately half of the patients lost their teeth due to periodontal lesions.

On the other hand, 9.5% of patients in IFD group (2/21 patients) and 12.2% of patients in RPD group (10/82 patients) lost their teeth adjacent to edentulous space during the observation period. Most of patients in RPD group (80%) lost their teeth due to periodontal lesions.

Regarding the opposing teeth to edentulous space, 4.8% of patients in IFD group (1/21 patients) and 8.5% of patients in RPD group (7/82 patients) lost their teeth during the observation period. The cause for tooth loss in the single case in IFD group was periodontal lesion, whereas in RPD group, majority of the patients lost their teeth due to caries.

3.5. Risk factors for remaining tooth loss

Regarding the whole remaining teeth, RPD restoration and gender (male) were the significant risk factors associated with remaining teeth loss (Table 3).

Analysis of the risk factors for tooth loss of the adjacent teeth to edentulous space identified only gender (male) as the significant risk factor, whereas none of the analyzed predictors was significantly correlated with tooth loss of the opposing tooth to edentulous space.

4. Discussion

Despite a thorough search in the literature, this study was the first report that simultaneously compared the survival rates of remaining teeth between IFDs and RPDs in patients with large edentulous cases. The results of Kaplan–Meier analysis followed by the Log-rank test indicated a significantly higher ten-year cumulative survival rate of whole remaining teeth in the IFD treated group (40%) compared with that in the RPD treated group (24.4%). These findings clearly suggest that IFD treatment has a protective effect of the remaining teeth in patients with large edentulous cases.

One may think that these results could be biased by the difference in sample size between IFD and RPD groups (of approximately 4 times). However, it is worth noting that this difference did not significantly affect the results because the statistics applied herein analyze the groups independently, and

Table 3
Risk factor for loss of remaining teeth (Cox proportional hazard model).

	Whole remaining teeth			Adjacent teeth to edentulous space			Opposing teeth to edentulous space		
	RR	95% CI	*p*-Value	RR	95% CI	*p*-Value	RR	95% CI	*p*-Value
Prosthesis: RPD	3.44	[1.07–11.02]	0.04	5.71	[0.87–37.69]	0.07	3.44	[0.31–38.91]	0.32
Mean age (y)	1	[0.97–1.02]	0.7	0.96	[0.91–1.02]	0.16	1.01	[0.95–1.07]	0.76
Gender: male	2.12	[1.12–3.99]	0.02	4.76	[1.26–17.42]	0.02	3.13	[0.71–14.32]	0.13
Missing unit: mandible	0.93	[0.46–1.86]	0.83	1.5	[0.36–6.30]	0.58	2.08	[0.43–10.2]	0.36
Missing pattern: bounded	0.62	[0.27–1.42]	0.26	1.33	[0.27–6.41]	0.73	2.86	[0.52–15.82]	0.23
No. of remaining teeth	0.92	[0.83–1.02]	0.11	0.89	[0.71–1.12]	0.33	0.87	[0.68–1.11]	0.26
No. of missing teeth	0.89	[0.77–11.02]	0.1	1.01	[0.77–1.33]	0.94	1.08	[0.81–1.45]	0.59

RR: relative risk; 95% CI: 95% confidence interval.

therefore, the analyses were not substantially influenced by variations in sample number.

Regarding the causes of tooth loss, in IFD group they were diverse, with no tendencies. On the other hand, approximately half of the patients in RPD group lost their teeth due to periodontal lesions. When age was taken in consideration, the results indicated that periodontal lesions were the most common and frequent causes of permanent tooth loss in over middle ages, which are in agreement with previous reports [11,12]. Nevertheless, these results should be analyzed with caution because of the significant difference in age between the two groups. Future studies with well-controlled larger samples may possibly clarify this point.

Regarding the teeth adjacent to edentulous space, the cumulative survival rates in both IFD and RPD groups were not significantly different. Interestingly, eight of ten lost teeth in RPD group were extracted due to periodontal lesions. Teeth adjacent to edentulous space are generally designed as abutment teeth of the RPDs. Therefore, as reported previously [3–5], it is possible that excessive occlusal overloading onto the abutment teeth could be a major factor or at least an aggravating factor involved in the loss of these teeth adjacent to edentulous spaces. Since this study did not discriminate the groups according to the design of the RPD retainer, future studies that investigate the retainer design in different classification groups and compare them with IFD group will bring more valuable information on this point.

As with teeth opposing the intended edentulous space, the cumulative survival rates were not significantly different between the two groups. Only one tooth was lost in IFD group during the observation period, and eight teeth were lost in RPD group (Fig. 2). Interestingly, the more frequent causes of tooth loss in RPD group showed a different trend compared with other subcategories. Four of 8 teeth were lost due to caries. One possible explanation could be that the opposing teeth to RPDs would be subjected to lower intensity occlusal forces compared to natural teeth or IFD and FPD treatments, because of the cushioning effect of the underlying supporting mucosa of RPDs. Additionally, occlusal adjustments of RPDs are usually performed to avoid horizontal/lateral forces. Therefore, it would be reasonable to expect lower incidence of traumatic periodontal lesions in the teeth opposing the edentulous space treated with RPDs.

It is of note, however, that most of the lost teeth were neither adjacent nor opposed to the edentulous space. As shown in Fig. 2, among the total number of 40 teeth lost in RPD group, 10 were adjacent to edentulous space, and 7 were opposing the edentulous space; and more than half (23 teeth) were not directly in contact with the prosthetic treatment. Among these 23 lost teeth, 9 of them were due to periodontal lesions, 9 of them were due to root fracture, and 5 of them were due to periapical lesions (none was due to caries). In other words, these 23 teeth were lost due to reasons that might not be related to the prosthetic treatment itself. A possible explanation for these results could be related to the protective effect attained by IFD treatment against occlusal overload on all remaining teeth in a long-term perspective. RPD treatment, on the other had, could induce changes in occlusal contact pattern in a long-spam particularly in such large edentulous cases, due to intrinsic resorption of the alveolar bone in the edentulous area supporting the RPD. Consequently, overloading forces on the remaining teeth could be related to the higher incidence of periodontal lesions or root fractures in RPD group. Another possible explanation could be an initial baseline difference between IFD and RPD groups in regards to the periodontal condition, which unfortunately was not investigated in this retrospective study. Further investigation is necessary to clarify this point.

In this study, we also attempted to detect the risk factors for remaining teeth loss. Multiple regression analysis identified RPD restoration and gender (male) as the significant risk factors for the whole remaining teeth loss. Since RPDs are partially supported by mucosa, torqueing forces from the prosthesis onto the abutment teeth during mastication are critical in large edentulous cases. Additionally, males are known to have a stronger biting force [13] than females; therefore, it is reasonable to have such a tendency for tooth loss in males, even in areas not directly in contact with the prosthesis. The results of the present study could also be influenced by other confounding factors, such as systemic diseases (e.g., diabetes), drinking and smoking habits [14–19], which were not evaluated herein. In addition, a control group of patients who did not wear either IFD or RPD was not included in this study, and therefore, no definitive conclusion can indeed be drawn. Future studies are needed to include these and other factors to shed more light on this point.

When a multiple regression analysis was performed for teeth adjacent to edentulous space, only gender difference was identified as the significant risk factor, while no risk factor was identified in the analysis for those teeth opposed to edentulous space.

5. Conclusions

This study showed that ten-year cumulative survival rates of the whole remaining teeth were significantly higher in IFD treated group compared to RPD group. On the other hand, there was no significant difference between the two groups in the survival rates of the teeth adjacent or opposing to edentulous space. Regarding the risk factors for loss of the remaining teeth (whole), RPD restoration and gender (male) were the significant risk factors. Within the limitations of this study, such as the lack of the examination of periodontal baseline condition, the present results suggest the possibility that IFD treatment preserves the remaining teeth in large edentulous cases.

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